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STATE OF THE GULF OF FINLAND IN 2003

Hannu Haahti & Pentti Kangas (Editors)

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ABSTRACT

In 2003 the surface temperature was low in early summer, but exceptionally high later on. The autumn cooling was rapid. In mid-summer the density stratification at the thermocline was very strong. After the unusually strong stratification in 2002, the near bottom oxygen conditions were still very poor until the last days of December.

Nitrate concentrations were at the normal level round the year 2003. The phosphate concentrations were very high at the near bottom layer due to very poor oxygen conditions during the whole year. In the very end of the year extraordinarily high phosphate concentrations were observed in the surface layer east of Helsinki due to effective mixing in the last days of December.

The spring bloom period in the Western Gulf of Finland 2003 was most intense since 1992, but no rising trend can be observed from 1992 to 2003. Of the other Baltic areas compared, the Western Gulf of Finland showed the highest index-values. This result can be related to the overall trophic state of these sea areas.

In the beginning of the year 2003 the levels of phosphate phosphorus in the surface water of the Gulf of Finland were clearly lower than in the previous years. However, the phosphate levels rose during the spring and remained high through the spring bloom, thus predicting strong cyanobacterial blooms if favourable weather conditions occurred. As surplus phosphate in the pre- and post-bloom period has been perceived as a precondition for extensive cyanobacterial blooms, a forecast for strong cyanobacterial blooms was released accordingly.

In 2003, two new invasive species were observed in the Gulf of Finland. A single individual of the euryhaline littoral prawn *Palaemon elegans* was caught near Hanko. The species is not expected to reproduce in the low salinities of the Gulf. In the port of Hamina, the North American littoral amphipod *Gammarus tigrinus* was found in littoral samples.

In the Gulf of Finland, herring catches were between 30000 and 50000 tons from 1980 until 2002, but a strong decrease occurred in 2003. Sprat catches increased rapidly during the latter half of the 1990s, and after a peak of 39000 tons at the turn of the century, catches decreased again in 2001-2003.

The concentrations of the classical organochlorines PCBs and DDTs in fish tissue, as well as those for the heavy metals lead, cadmium and mercury, remained in 2002 roughly on the same level as in the previous year. In the long run, however, the slowly decreasing trend in organochlorine concentrations is evident.

In 2003 number of detected illegal oil spills decreased from ca one hundred to 40, but it is too early to say if it is a trend. The majority of the spills was found in the shipping routes on the open sea. The sea traffic is steadily increasing in the Gulf of Finland. This is especially true for the oil transportation which is estimated to double from 2003 to 2010. This development means higher risks of oil accidents and possible serious damages for the nature of the Gulf of Finland.

Key words: Gulf of Finland, hydrography, nutrients, macrozoobenthos, plankton blooms, alien species, fishing, PCB, DDT, heavy metals, oil

INTRODUCTION

This report is a part of the Estonian - Finnish - Russian cooperation on the Gulf of Finland. It has been compiled of research and monitoring results of collaborating institutes. Those results from the year 2003 have been used, which have been available at this stage. For some parameters more time is required for analysing and checking the results. The aim of this report has been to serve the public with fresh information on the state of the Gulf of Finland.

NUTRIENT LOADING

The external nutrient inputs of both N and P to the Gulf of Finland have decreased by about 40 % from the late 1980s to 2000 (Fig. 1). The decrease was especially steep during the first half of the 1990s. The change was only for a part due to active water protection measures in the surrounding countries of the Gulf. The most important factor was the economic changes in Russia and Estonia in the beginning of the 1990s after the collapse of the former Soviet Union. Thus, especially the loading to the eastern Gulf has decreased. Despite these decreases in loading, the nutrient load of the late 1990s to the whole Gulf was 2 to 3 times the average of the whole Baltic Sea area; in the eastern Gulf the corresponding factor was about 4 to 5 (Pitkänen & al. 2001).

The annual external nutrient inputs (year 2000) to the Gulf of Finland is about 6 400 t of total P and 120 000 t of total N (Kiirikki & al. 2003). From theses amounts rougly 70 % of P and 50 % of N enter the Gulf in its easternmost part. About 40 % of the P (2 800 t a-1) and 60 % of N (77 000 t a-1) of the inputs are estimated as readily bioavailable for primary producers. The largest single source of bioavailable P is the city of St. Petersburg, while the River Neva is responsible for the largest single proportion of bioavailable N. The mean ratio for bioavailable N:P (ca. 30 w/w) of the inputs demonstrate a clear excess N when compared to the optimum Redfield ratio (7.2 w/w) for primary production in the sea.

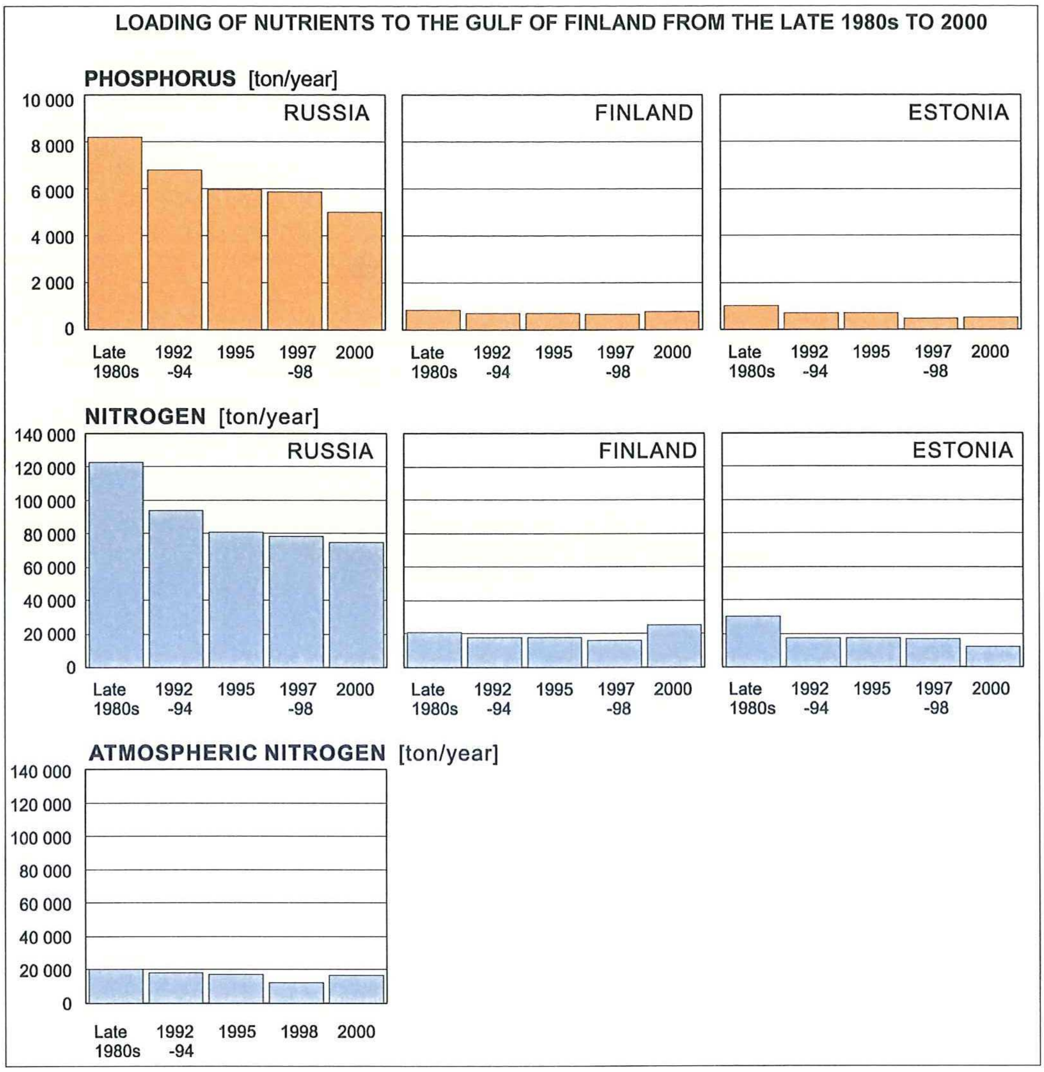


Fig. 1. Trends of nutrient loading into the Gulf of Finland from late 1980s. (Source: SYKE, Mikko Kiirikki.)

HYDROGRAPHY AND OXYGEN CONDITIONS

In 2003 the salinity and density stratification were less pronounced than in 2002. The salinity was, however, rather high at mid to bottom depths in the central gulf (LL7) (Fig. 2) in comparison to the last 10 years. In mid-summer the density stratification at the thermocline was very strong.

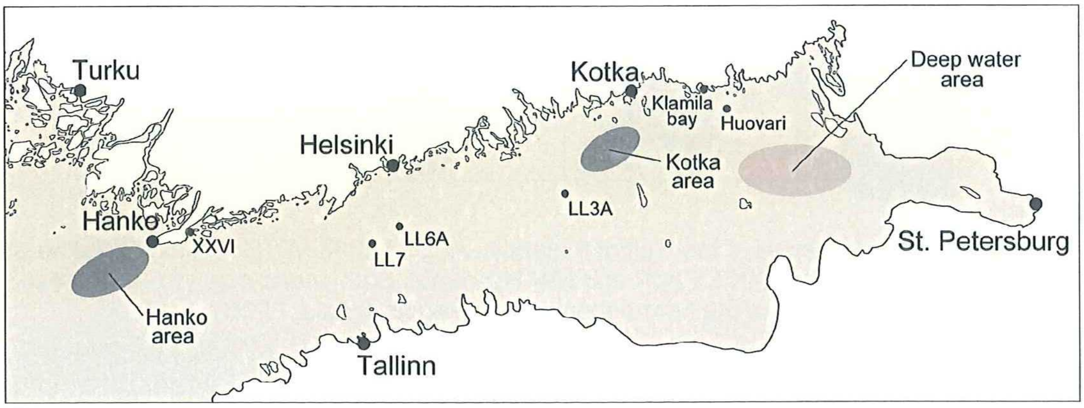
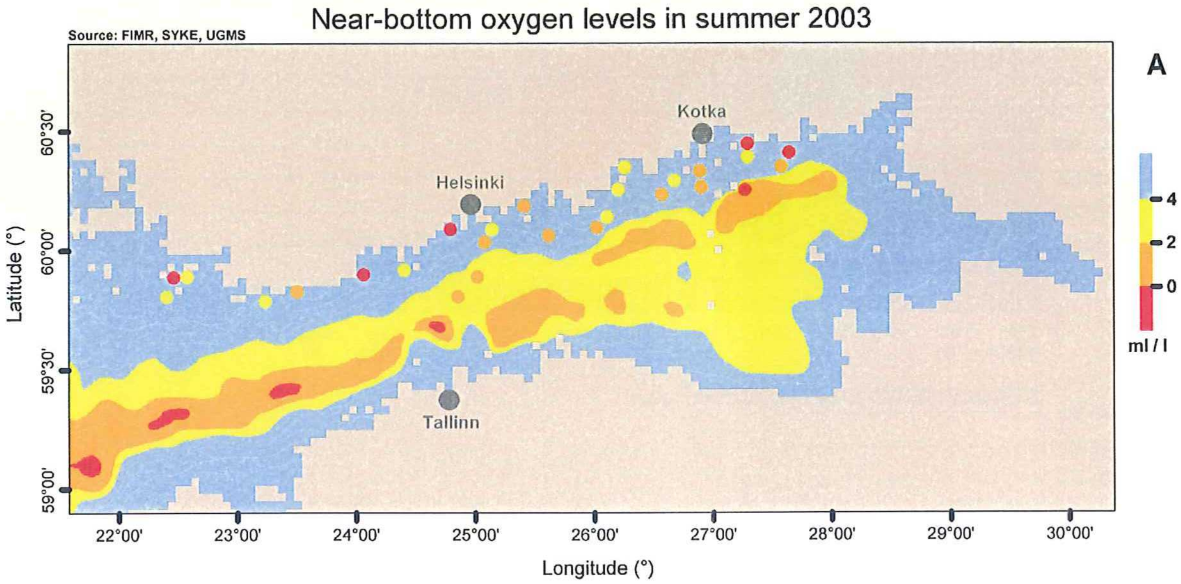


Fig. 2. Sampling sites.

The year 2003 differed from the previous one in sea temperatures clearly. Sea surface temperature was below that of previous years until the beginning of July. However, in the thermal mid-summer at the end of July and at the beginning of August the sea surface temperature was exceptionally high. There was a very steep thermocline at about 10 m depth in the middle of the gulf (LL7). The autumn cooling was rapid and autumn conditions rather normal or even cool. After the unusually strong stratification in 2002, the near bottom oxygen conditions were still very poor (Fig. 3). After some stormy days in late December the water mass was mixed throughly east of Helsinki and therefore the oxygen situation changed to very good also in the bottom layer by the end of the year.



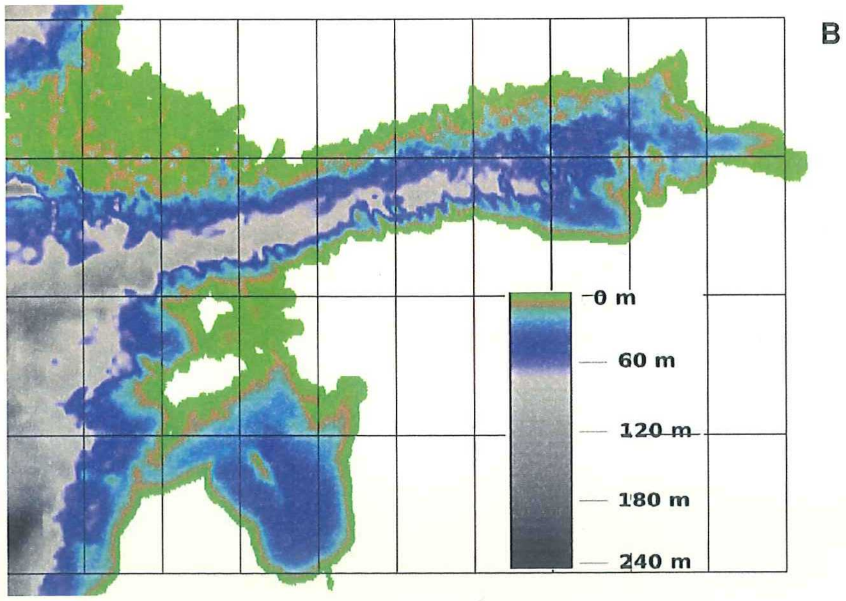
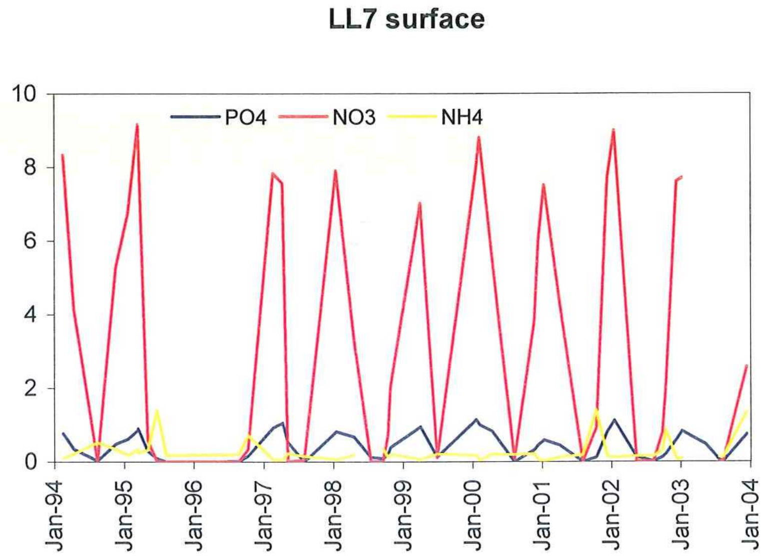


Fig. 3. Near-bottom oxygen levels of the Gulf of Finland in August 2003 (A). Compiled by Janne Bruun, FIMR, on the basis of data by SYKE, FIMR and NW Hydromet. Bathymeric map of GoF (B) explains conditions of the near-bottom water (Seppo Kaitala, FIMR).

NUTRIENTS

Nitrate concentrations were at the normal level round the year 2003 (Figs. 4, 5, 6). The slow decreasing trend in deep water was still observed (Perttilä, (ed.) 2003) (Fig. 4). The phosphate concentrations were very high at the near bottom layer due to very poor oxygen conditions during the whole year and so phosphate was liberated from the sediment. In the very end of the year extraordinarily high phosphate concentrations were observed in the surface layer east of Helsinki due to effective mixing in the last days of December. At the turn of the year surface phosphate concentrations varied between 0.71 and 1.42 µmol/l in the whole Gulf of Finland. (Sampling sites, see Fig. 2.)



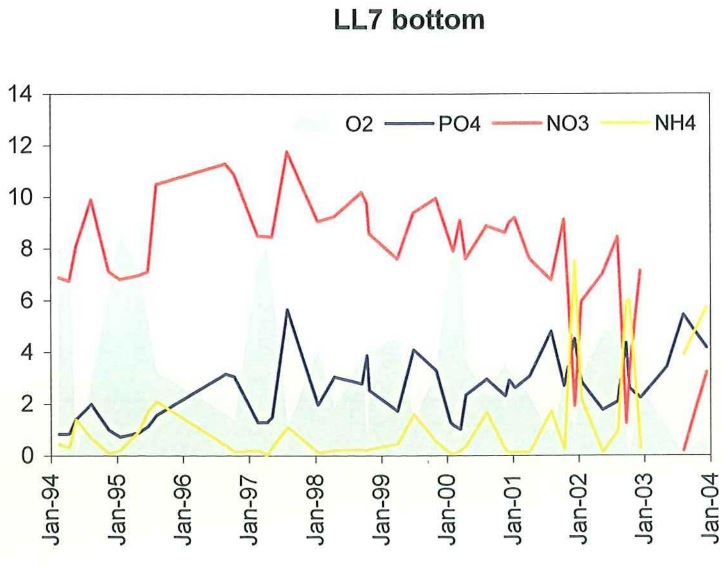
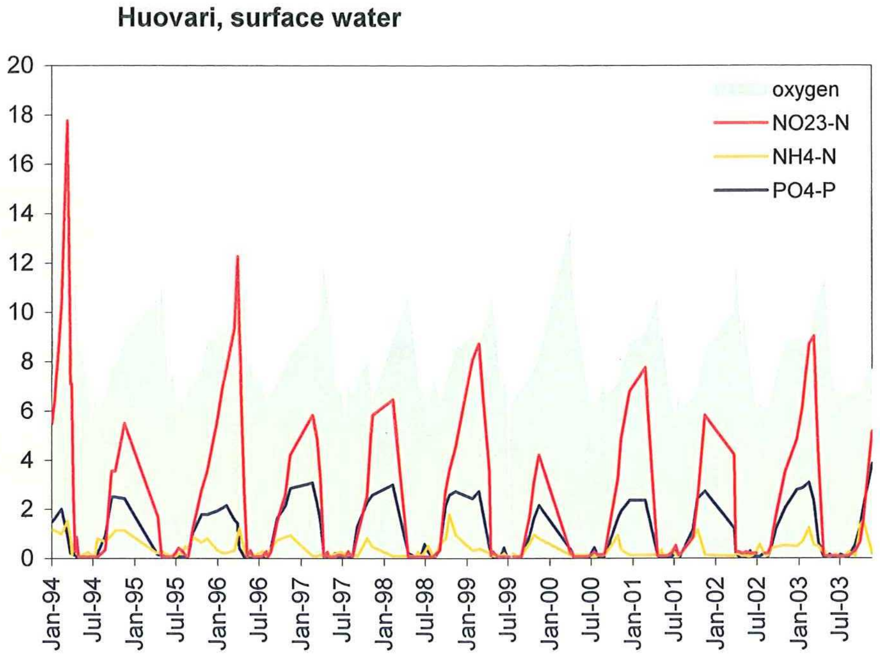


Fig. 4. Nutrient concentrations of surface and near-bottom water in the middle of the open Gulf of Finland during the last ten years. (Source: FIMR, Hannu Haahti.)



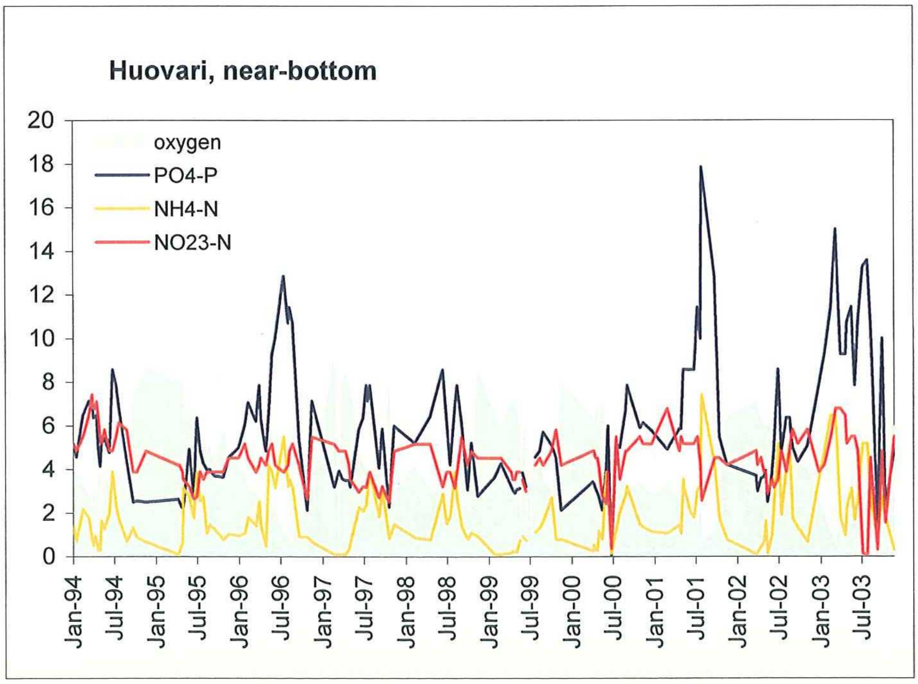
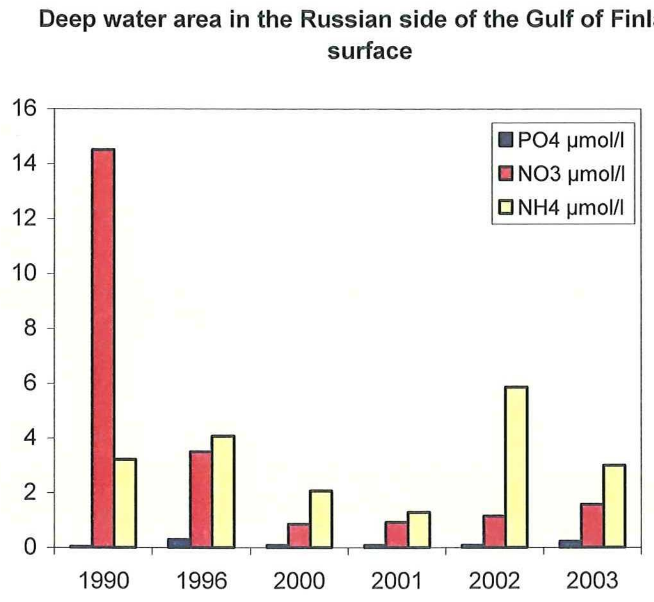


Fig. 5. Nutrient concentrations of surface and near-bottom water at Huovari, easternmost Finnish coastal waters, during the last ten years. (Source: SYKE, Pirkko Kauppila.)



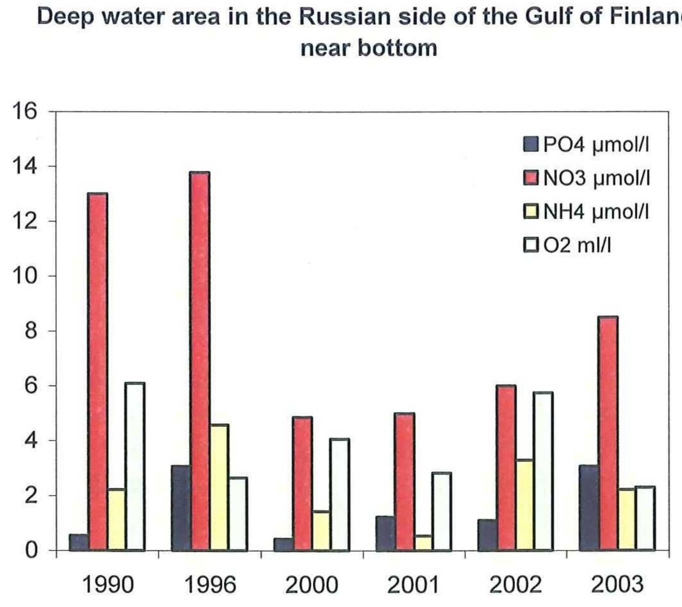


Fig. 6. Mean nutrient concentrations of surface and near-bottom water of the Russian deep water area, during the last ten years. (Source: NW Hydromet, Svetlana Basova.)

MACROZOOBENTHOS

Results of macrozoobenthos sampling in the northern side of GoF indicate a poor state of communities in 2003 (Fig. 7). Approximately 80 % of the investigated coastal basins were devoid of macrofauna, which is the worst result in the period 2001-2003. The state of the communities was worst in the east, and the deep basins investigated in Kotka and Hamina archipelagos were mostly devoid of macrofauna. This is obviously due to periodic hypoxia, which hampers the recolonization and development of a normal bottom fauna. The sediment surface was mostly anoxic when macrofauna was absent. Abundant macrofauna with a typical species composition was found primarily at sites with a less pronounced sedimentation.

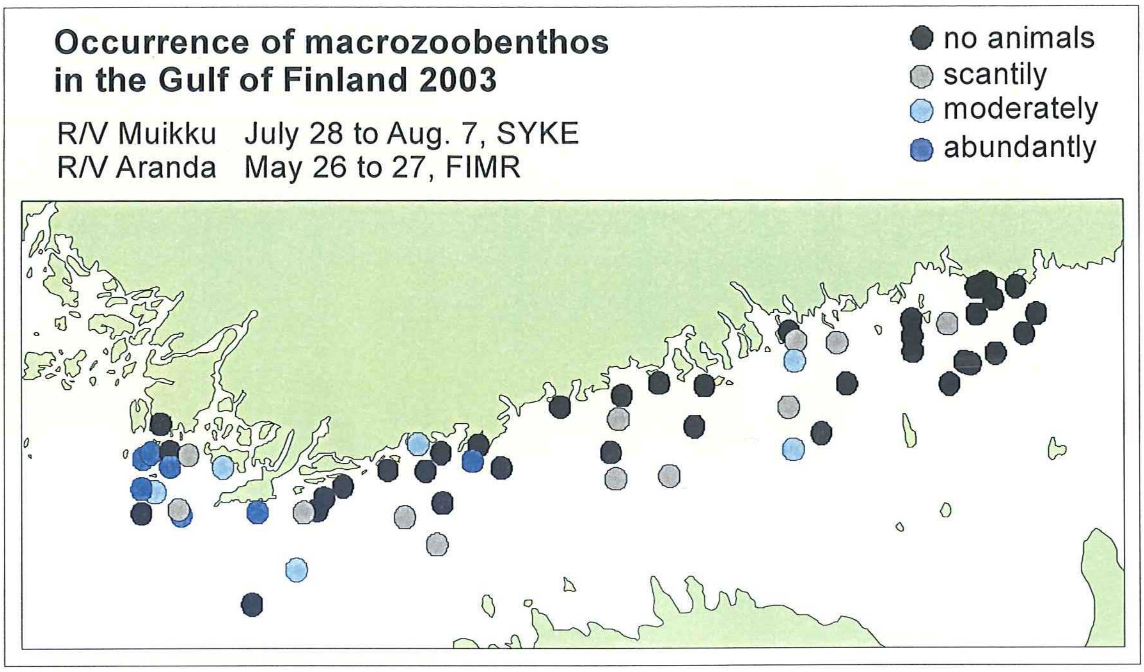
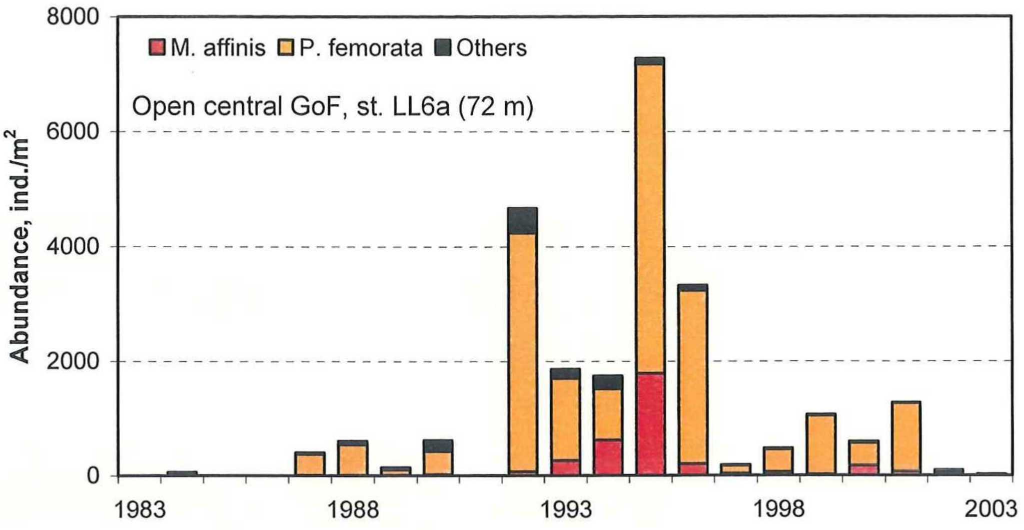


Fig. 7. Occurrence of macrozoobenthos in GoF during the cruises of R/V Muikku and R/V Aranda in summer 2003. (Source: FIMR, Ari Laine and SYKE, Pentti Kangas.)

Monitoring data from the central and western GoF show that macrozoobenthos is also very poor in the deep open sea (Fig. 8). The abundant community that prevailed in the middle of the 1990s has declined due to poor oxygen conditions (Laine & al. 1997). This was due to the re-establishment of stratification after salt water inflows. These conditions seem to continue and macrozoobenthos is not able to colonize the deep areas.

In the archipelago of the northern GoF, a change in the species composition has taken place (Fig. 8). The abundant amphipod (*Monoporeia affinis*) dominated communities have been replaced by the Baltic clam, *Macoma baltica*. This change has been observed both in Hanko (Laine & al. in prep.) and Helsinki areas (Laine & al. 2003). The initial reason for this change is unclear.



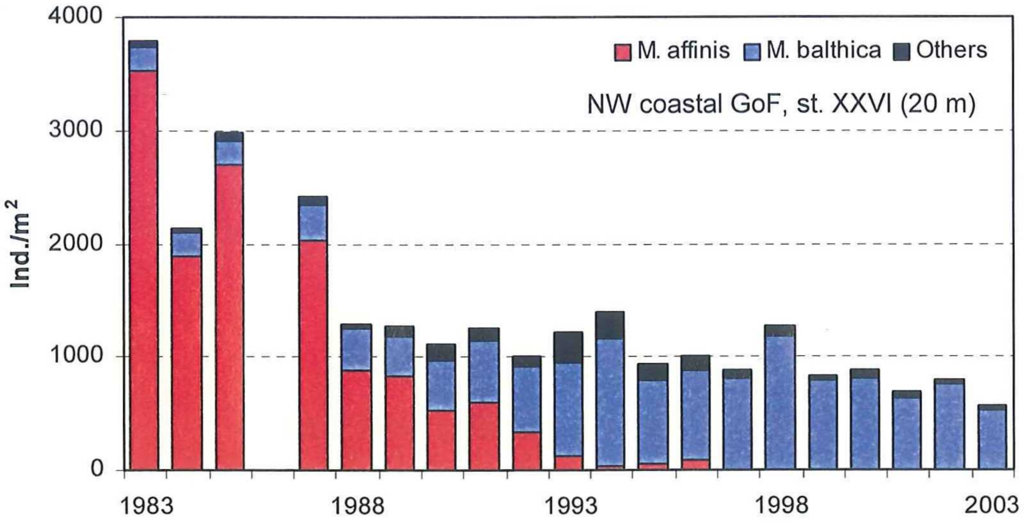


Fig. 8. Macrozoobenthos trends in the open central GoF (upper) and in the NW coastal GoF (lower). (Source: FIMR, Ari Laine and SYKE, Pentti Kangas.) Locations see Fig. 2.

PHYTOPLANKTON BLOOMS IN THE GULF OF FINLAND

Spring bloom

The intensity of the spring bloom period was estimated by the intensity index which takes into account both the strength and duration of the bloom. This index was based on Alg@line shipborne data.

Spring bloom period in the Western Gulf of Finland 2003 was most intense since 1992, but no rising trend can be observed from 1992 to 2003. Of the areas compared, the Western Gulf of Finland showed the highest index-values (Fig. 9). This result can be related to the overall trophic state of these sea areas.

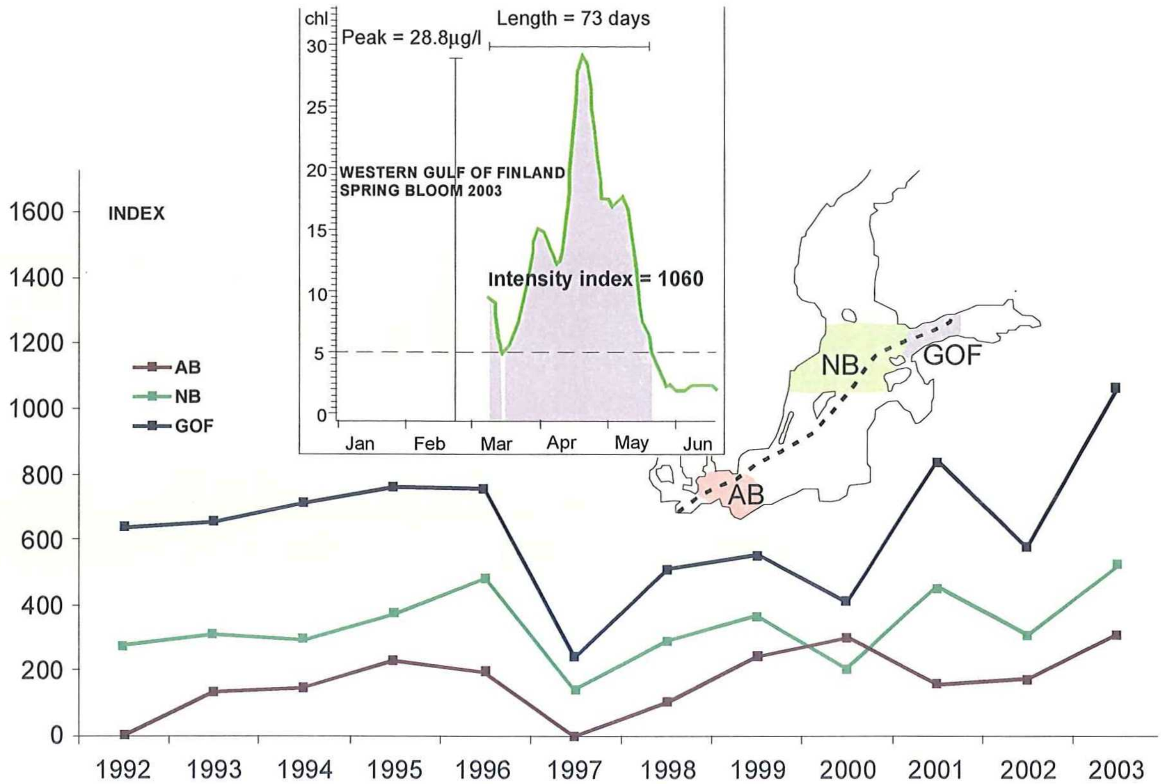


Fig. 9. The spring bloom intensity index from 1992 to 2003 in the Western Gulf of Finland (GoF) is presented with blue line (values from Arkona Basin (AB) and the Northern Baltic Proper (NB) are also shown). The route of ship is indicated in the map. Inset: seven-day running average of chlorophyll *a* curve (green) in 2003 in the Western Gulf of Finland. The shaded area illustrates the intensity index of the spring bloom (spring bloom threshold= broken line) (Figures: FIMR, Vivi Fleming and Seppo Kaitala).

Late-summer cyanobacterial blooms

In the beginning of the year 2003 the levels of phosphate phosphorus in the surface water of the Gulf of Finland were clearly lower than in the previous years. However, the phosphate levels rose during the spring and remained high through the spring bloom, thus predicting strong cyanobacterial blooms if favourable weather conditions occurred (Fig. 10). As surplus phosphate in the pre- and post-bloom period has been perceived as a precondition for extensive cyanobacterial blooms, forecast for strong cyanobacterial blooms was released accordingly.

In the Finnish sea areas, the intensity of the cyanobacterial blooms of the summer of 2003 turned out to be lower than expected and weaker than in previous years. Although the summer period was very warm, extensive cyanobacterial surface accumulations occurred only during the latter part of July. Thus, the occurrence of cyanobacteria cannot be predicted solely based on information on nutrient concentrations, but hydrodynamic phenomena (upwellings, advection) and meteorology (winds) strongly affect the observed cyanobacterial biomasses, and even more strongly the occurrence of surface accumulations.

Although the intensitivity of cyanobacterial blooms was generally only moderate, but locally heavy, restricted blooms occurred in many locations in the Gulf of Finland at the turn of July-August. During that period the most common bloom-forming cyanobacteria were *Nodularia spumigena*, *Anabaena* spp. and *Aphanizomenon flos-aquae*. In the coastal areas of the Gulf of Finland there were still locally intensive cyanobacterial blooms in August. In the Baltic Proper, the cyanobacterial blooms were more intensive than in the Gulf of Finland (Fig. 10, right).

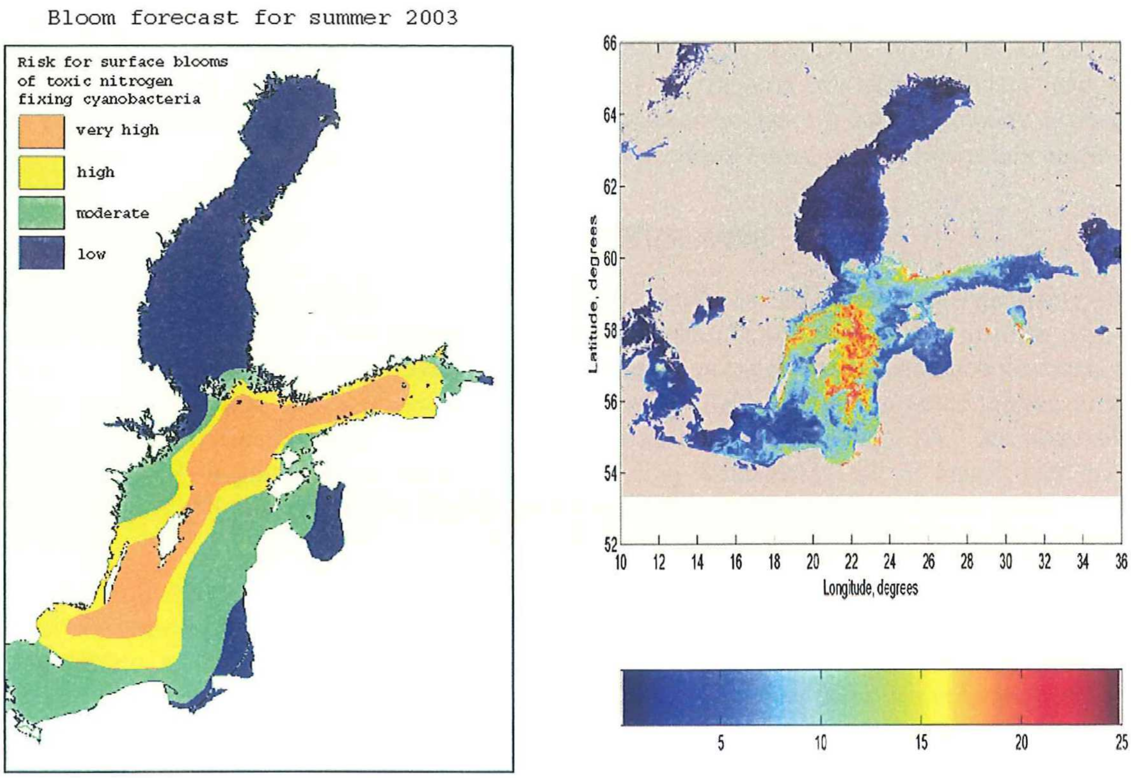


Fig. 10. Cyanobacterial bloom forecast for summer 2003 (left, source: SYKE Mikko Kiirikki). The cyanobacterial blooms in the Baltic Sea as based on images taken from July 17-30, 2003 (right, source: SYKE, Jenni Vepsäläinen). The scale refers to chlorophyll *a* concentration.

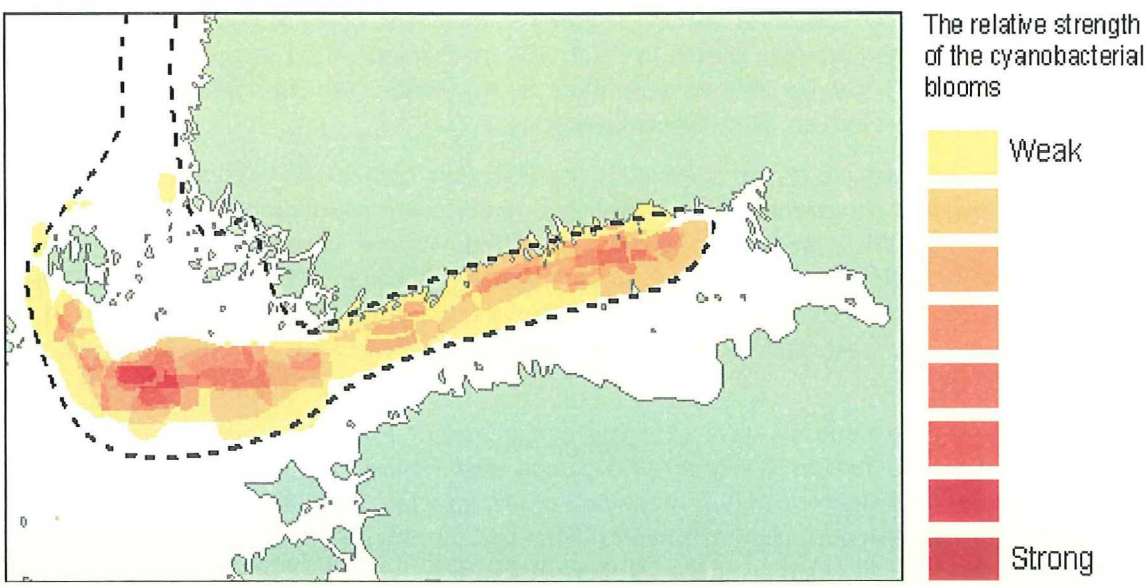


Fig. 11. The cyanobacterial blooms in the Gulf of Finland June 1 to August 31, 2003. The data is mainly based on the observations made by the pilots of the Finnish Frontier Guard (observed area = dashed line). (Figure: FIMR, Joona Lehtomäki.)

Toxicity of the bloom forming cyanobacteria

Generally, the blooms of the cyanobacterium *Nodularia spumigena* have always been hepatotoxic in the Baltic Sea, and this was also true in 2003. The blooms formed solely by another abundant cyanobacterium *Aphanizomenon flos-aquae* have never been toxic. However, blooms consisting both of *Aphanizomenon* and species of the genus *Anabaena* have been observed to be toxic.

INVASIVE SPECIES

The North-American polychaete *Marenzelleria viridis* and Ponto-Caspian cladoceran *Cercopagis pengoi*, which were first recorded in the Gulf of Finland in 1990 and 1992, have become established species in macrozoobenthos and zooplankton communities, respectively. *Marenzelleria viridis* is found commonly in coastal areas around the Gulf, only occasional records of single specimens have been made in the open sea. The species has been relatively low in abundance and biomass (Fig. 12), higher values have been found in the easternmost gulf (Koporskaya Bay), contributing to 90 % of total zoobenthos biomass. In 2003, *Cercopagis pengoi* reached two peaks in late July and late August in the easternmost Gulf where it formed 84 % of total zooplankton biomass.

The zebra mussel *Dreissena polymorpha,* which is common in the easternmost Gulf (Neva estuary/Vyborg Bay), has been found in rather low densities in the Finnish archipelago since the first records in 1995, having a western distribution limit in the Porvoo area. In 2003, a remarkable colonization by juveniles was observed at several sites in the Bay of Loviisa, with densities as high as 3300 individuals per square meter. Also, a new settlement of adults and juveniles, with very high densities (up to 100 000 individuals per square meter) was discovered outside the cooling water discharge of Loviisa Nuclear Power Plant. This population is obviously favored by the warm discharge waters and could act as significant source of a further increase of the species in the area.

Despite its long presence in the Baltic Sea, the Chinese mitten crab *Eriocheir sinensis* has been observed only occasionally in the Gulf of Finland. In 2003 an unusually high number of findings of the species in several parts of the Gulf of Finland (incl. Estonian and Finnish coasts and the Neva Bay) has been recorded. Although the species is difficult to monitor, long-term observations made in Muuga Bay since 1991 indicate that the increase started in 2002. The mechanism of the invasion remains unclear, since the species should not be able to reproduce in the Baltic Sea and the closest permanent populations are located in German North Sea estuaries.

In Neva Bay area, two invasive littoral amphipods, the Baikalian *Gmelinoides fasciatus* and the Ponto-Caspian *Pontogammarus robustoides*, have established reproducing populations that are increasing in numbers. Compared to 2001, there has been a 5- to 6-fold increase in their density. Amur sleeper (*Perccottus glenii*), a fresh water fish of Far Eastern origin, has become very common in the Neva Bay area and has been recorded in Vyborg Bay also. The Neva estuary may thus serve as a donor of these species to the rest of the Gulf, and in case of *Gmelinoides* and *Perccottus*, to Finnish inland waters also.

In 2003, two new invasive species were observed in the Gulf of Finland. A single individual of the euryhaline littoral prawn *Palaemon elegans* was caught near Hanko. The species is not expected to reproduce in the low salinities of the Gulf. In the port of Hamina, the North American littoral amphipod *Gammarus tigrinus* was found in littoral samples. This species should be actively monitored since it has established permanent populations in the southern Baltic Sea.

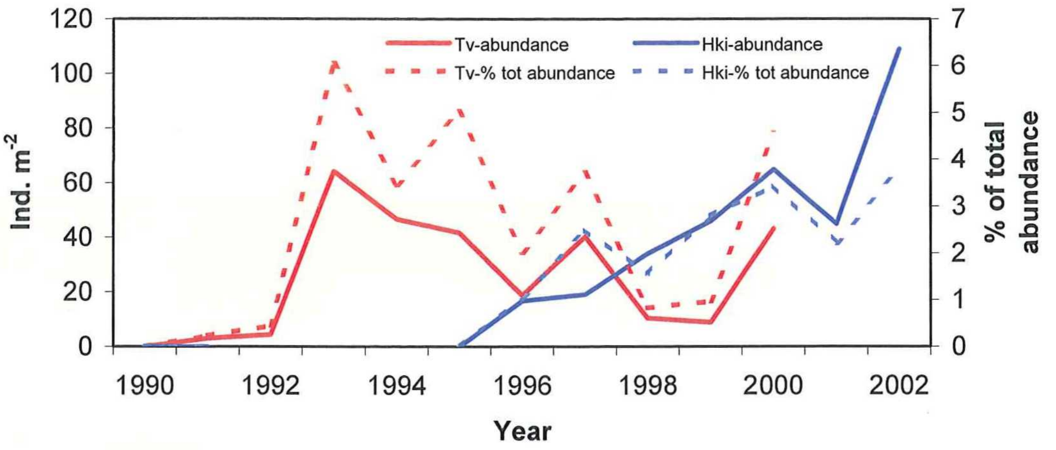


Fig. 12. Changes in the abundance and contribution to total macrozoobenthos abundance of *Marenzelleria viridis*, based on zoobenthos monitoring data collected in the outer archipelago areas in Tvärminne (Tv) (Hanko) and Helsinki (Hki) (Finnish Institute of Marine Research, Finnish Environment Institute and City of Helsinki Environment Centre).

FISHING

The fish assemblage of the Gulf of Finland is a mixture of marine and freshwater fish. The marine clupeid species, herring and sprat are the most abundant species in the fish assemblage and they constitute the majority of the catches in the Gulf of Finland. Few separate assessments of the abundance of clupeid fish have been done because of difficulties to separate different populations e.g. due to the migrations of fish between the Gulf of Finland and the Baltic Sea Proper. However, fluctuations in catches reflect the changes in abundance of the fish species, although the catch levels also include the influences of political, fisheries management and market factors to a varying degree. In the Gulf of Finland, herring catches were between 30000 and 50000 tons from 1980 until 2002, but a decrease occurred in 2003. Sprat catches increased rapidly during the latter half of the 1990s, and after a peak of 39000 tons at the turn of the century, catches decreased again in 2001-2003. Although cod was abundant and the catches were high in the end of 1970s and in the beginning of 1980s, the cod stock collapsed and this species has been absent since the year 1990 (Fig. 13). The abundance of cod is largely determined by suitable hydrographic conditions in the spawning grounds in the Baltic Proper. Additionally, intensive fishing in the present distribution area of cod nowadays restricts the recovery of the stock.

The changes in the growth rates of herring and sprat have been dramatic during the last few decades. Herring growth rates were high in the beginning of 1980s, but until 1990s weights-at-age had decreased to c. 50 %. A similar decrease in sprat growth rates occurred during 1990s. Changes in growth rates were obviously due to changes in hydrography and adjacent changes in zooplankton community, leading to poor feeding conditions for herring and sprat. Additionally, density-dependent mechanisms (i.e. competition between the planktivorous fish) may influence the growth rates.

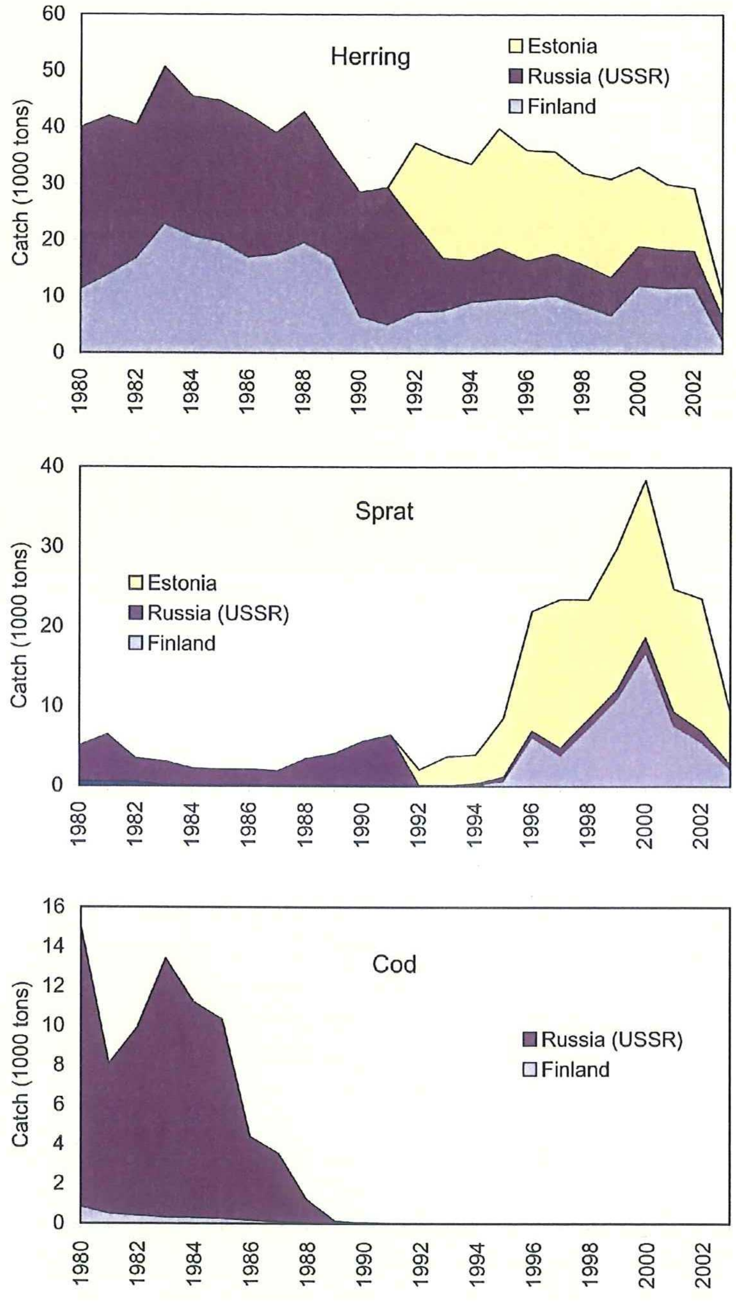
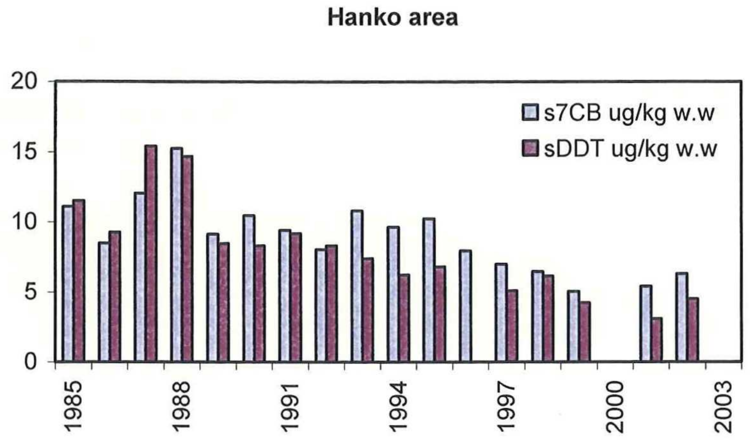


Fig. 13. The catches of herring, sprat and cod in 1980-2003 in the Gulf of Finland. Sources: ICES Baltic Sea Fisheries Assessment Working Group 1995-2004; Heikki Peltonen (unpublished); Jukka Pönni (unpublished); Kornilovs (unpublished); Shurukin, Popov and Bogdanov (unpublished).

HARMFUL SUBSTANCES

PCB and DDT

Results on organochlorine compounds for 2003 will be available only later, but the time series (Fig. 14) clearly show the trends of concentrations in muscle of two year old Baltic Herring at two Finnish coastal areas. The values presented here are total PCB concentration (sum of 7 main representative PCB components) and total DDT concentration (DDT plus the metabolites DDE and DDD). The concentrations of both compounds have been slowly decreasing in east from the 1980s onwards, but especially during the last five years. In the western area, however, the decrease of concentrations recently levelled off. The development of PCB and DDT in pike muscles shows corresponding consistent decreasing trends in Klamila Bay, easternmost Finnish coastal waters (Fig. 15).



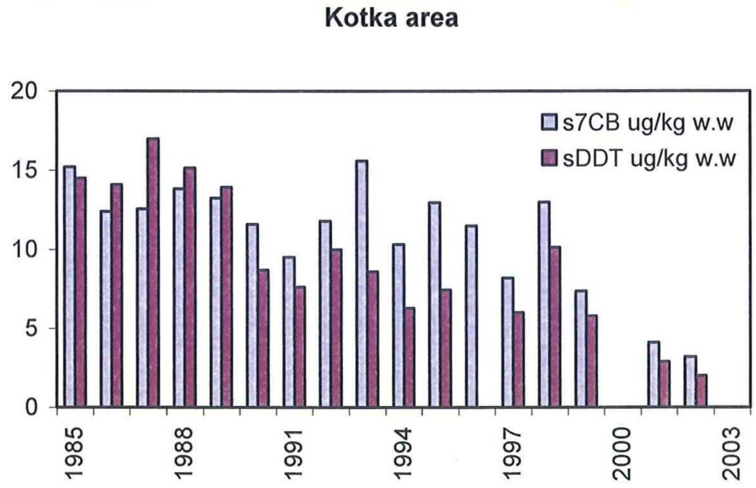


Fig. 14. Sum of 7 PCB-congeners (sPCB) and sum of pp'DDE, pp' DDD and pp' DDT (sDDT) in the muscle of Baltic Herring. (Source: FIMR, Hannu Haahti.) Locations see Fig. 2.

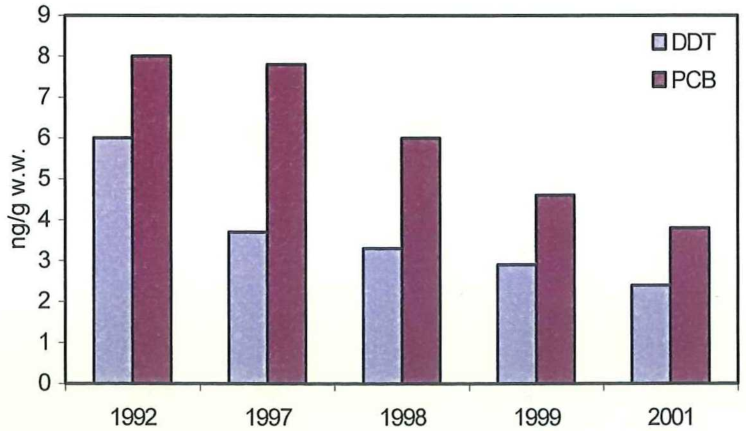
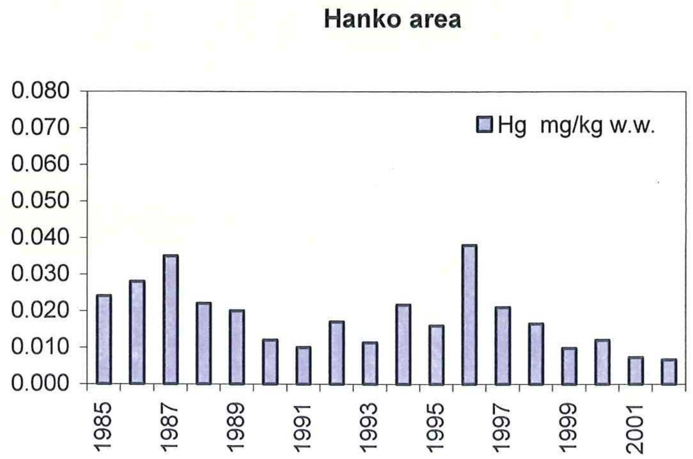


Fig. 15. PCB and DDT trends in pike muscle (Esox fluviatilis) in Klamila Bay, easternmost Finnish coastal waters. (Source: SYKE, Jaakko Mannio.) Locations see Fig. 2.

Heavy metals

The most recent monitoring results on the concentrations of heavy metals in herring muscle are available for the year 2002. The concentrations of mercury have strongly decreased at both studied areas of the GoF since the middle 1990s. The development has been congruent with this in the other sea areas of Finland as well. It is notable that mercury in Kotka area fell to less than a half from 2001 to 2002 (Fig. 16).



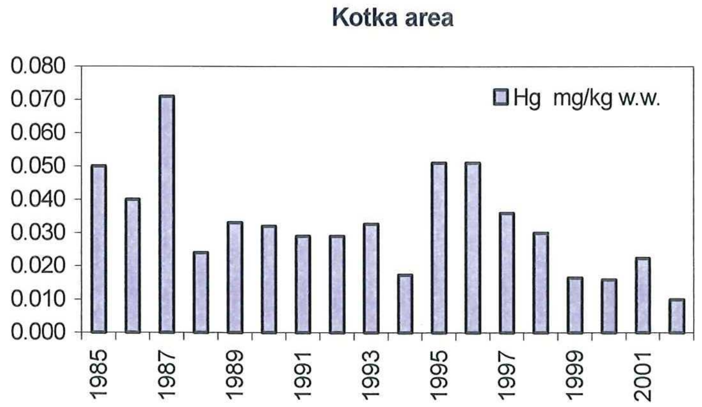


Fig.16. Trends of mercury in the Baltic Herring muscle. (Source: FIMR, Mirja Leivuori.) Locations see Fig. 2.

OIL POLLUTION

The number of detected illegal oil spills to the Gulf of Finland has dropped markedly since the maximum in 2001, being just 40 in 2003 (Fig. 17). It is, however too early to state if this decrease is a trend. As seen on the surveillances of the Finnish Frontier Guard (Fig. 18), the spills are located near the shipping routes on the open sea.

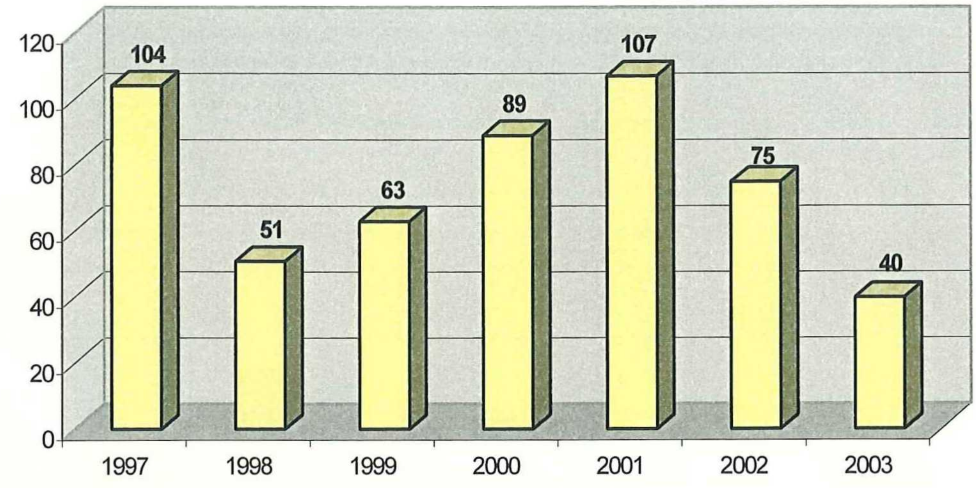


Fig. 17. Oil spills detected by aerial surveillance in 1997-2003 in the Finnish response region. (Source: SYKE, Heli Haapasaari.)

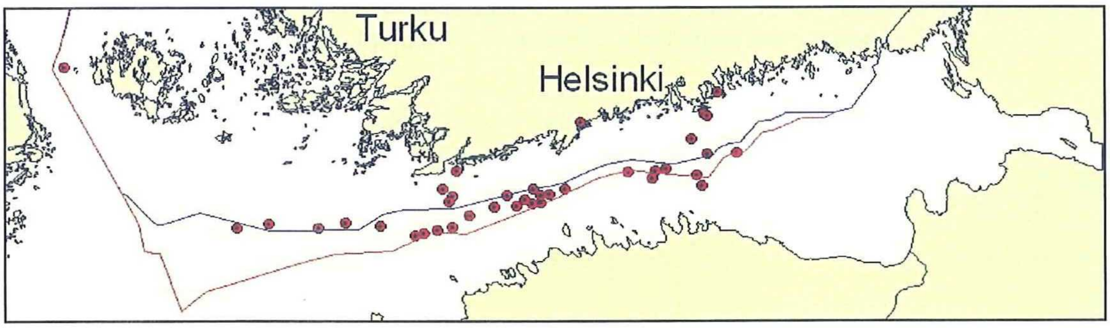


Fig. 18. Location of the detected oil spills in 2003. (Source: SYKE, Heli Haapasaari and Finnish Frontier Guard.)

Ship traffic has continuously increased during the last ten years, and ship visits in the Finnish harbours of the Gulf of Finland is now approaching 20 000 per year (Fig. 19). The transportation of oil is increasing fast (Fig. 20), and is estimated to grow strongly in future from the recent approx. 80 million tons per year.

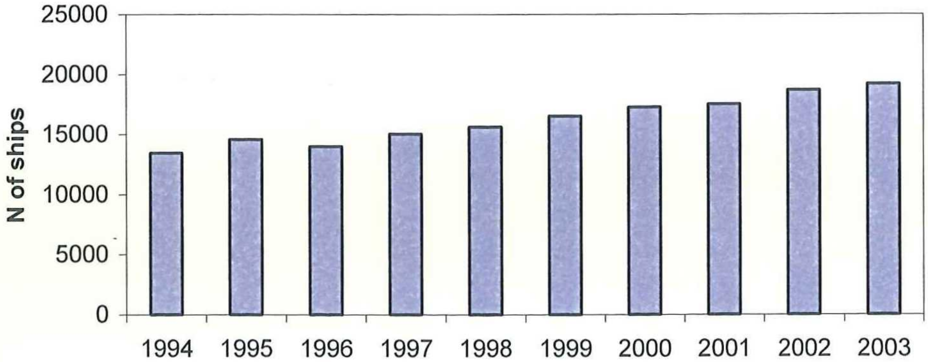


Fig. 19. Number of ship visits in the Finnish ports of the Gulf of Bothnia. (Source: Finnish Maritime Administration, Harry Federley.)

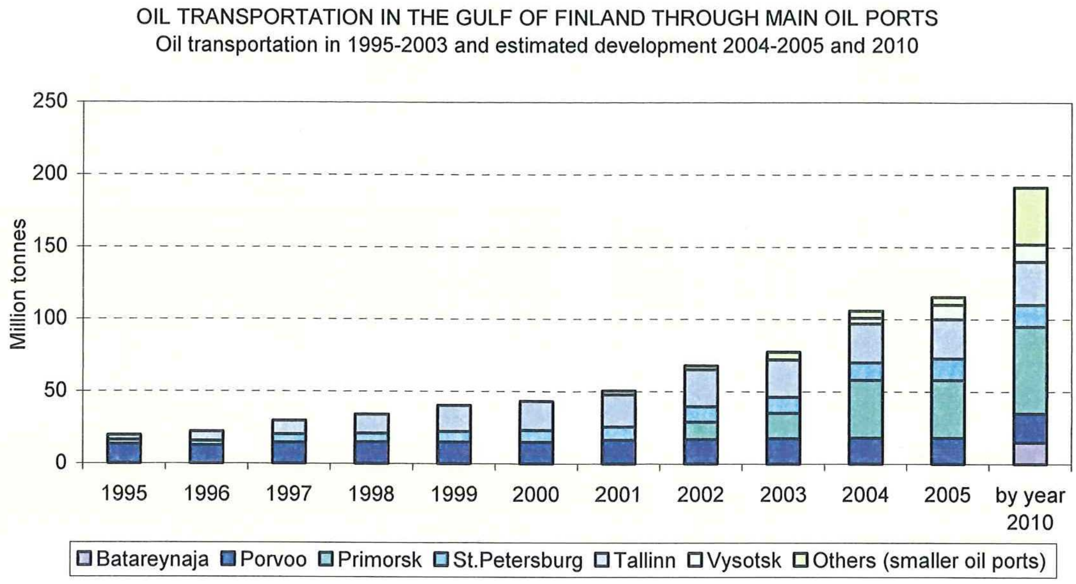


Fig. 20. Oil transportation in the Gulf of Finland through main oil ports 1995 to 2003. Estimated development from 2004. (Source: VTT, Jorma Rytkönen.)

With the fast growth of sea traffic the probability of oil spills may likewise increase. According to a HELCOM study (SSPA Maritime Consulting 1995), the number of annual accidents could grow to 6-7 in 2010. The maximum size of those bunker oil spills would be 100-200 tons. The size of cargo oil spills would vary from some hundreds of tons to thousands of tons of oil. This kind of development would seriously damage the environment of the Gulf of Finland and cause harm to e.g. recreation and other uses of coastal areas.

To reduce oil pollution of the sea, several actions have been taken by HELCOM, IMO, EU and local authorities. There are, e.g. programs to assess maritime traffic risks, systems to control the traffic, new equipment to combat pollution in ice conditions, technical prerequisites for ships and drifting models. The Baltic Sea recently obtained the status status of a particularly sensitive sea area (PSSA) in IMO, the International Maritime Organisation. That status will work in favour of protecting the Baltic Sea.

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